NAHUEL HUAPI NATIONAL PARK, ARGENTINA: CONSERVATION EFFECTIVENESS ASSESSMENT THROUGH MONITORING SMALL MAMMAL COMMUNITIES

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ABSTRACT

Protected areas are the cornerstone of conservation strategies, but their effectiveness is increasingly questioned. In Argentina's Nahuel Huapi National Park, we compared small mammals in unprotected areas and areas with three protection levels: (1) human activity forbidden, (2) recreation can be authorised, and (3) authorised tourism and extractive uses. A capture-mark-recapture study on five plots in each type of area included a trapping effort of 41,600 traps/night. In 2015, we trapped seven native rodent species and an endemic marsupial. In 2016, we captured the same species except for one rodent. Species richness did not vary among protection levels. However, greatest abundances were in the highest protection level and lowest abundances in the lowest level. We found scant evidence that the Nahuel Huapi National Park protection system substantially conserves small mammals. However, higher abundances in the highest protection level suggest direct human interaction negatively affects this assemblage.

Key words: capture-recapture, community, conservation

INTRODUCTION

Protected areas (PAs) are a key component of biodiversity conservation (Mascia & Pailler, 2011). Target 11 of the Aichi Biodiversity Targets proposes that they must be effectively and equitably managed (CBD, 2010), yet recent publications increasingly question the success of PAs in conserving biodiversity (Barnes et al., 2017; Barnes et al., 2016; Coad et al., 2019; Coetzee et al., 2014; Geldmann et al., 2018). A study published in 2014 found that species richness and abundance inside some PAs in South America were lower than outside (Coetzee et al., 2014).

Developed countries established PAs more than a century ago; however, the process began later in developing countries. Argentina is an exception. Land that would come to constitute Nahuel Huapi National Park (NHNP) was set aside in 1906; in 1922 the area was declared a National Park with the main goal of avoiding the destructive exploitation of forests and preserve the beautiful natural landscape (APN, 2013), and it constitutes the first PA in Latin America (Rivarola et al., 2021). NHNP is located in northwestern Argentinian Patagonia. Its original 717,261 ha are subdivided into three legal categories (Martin & Chehébar, 2001; Rivarola et al., 2021). Although the main purpose of all categories is to promote conservation and preservation of natural ecosystems and cultural values, the uses and activities vary among levels:

a. Strict Natural Reserve (75,525 ha designated in 1990): IUCN Category Ia, (Margutti & Arosteguy, 2019): In these areas, surrounded by National Park, human activity, apart from scientific research, is prohibited.
b. National Park (491,881 ha): IUCN Category II, (WDPA, 2017): Extractive use and tourist infrastructures are not permitted. Recreational use can be authorised.
c. National Reserve (225,380 ha designated in 1968): IUCN Category VI (WDPA, 2017): Tourist infrastructure is allowed. These are buffer zones between protected and unprotected land. Extractive use may be authorised. Furthermore, approximately 60 per cent consists of private properties, and livestock are common (Rusch, 2002).

We compared the small mammal species richness and abundance in these three management categories. A fourth conservation category, Wildlife Natural Reserve (IUCN Category Ib), was created in 1994 but was not analysed in the present study. NHNP aims to protect an ecological gradient comprising high Andean forest, Valdivian temperate forest and steppe. The Global 200 World Wildlife Fund conservation science programme identified Valdivian Temperate forest as a 'Critical or Endangered' ecoregion (Olson & Dinerstein, 1998). These temperate forests are isolated from other forest by more than 1,000 km (Pearson, 1983). Unique ecological and evolutionary processes have occurred in these forests, leading to low vertebrate biodiversity, a high degree of endemism (Barnosky et al., 2001), and an unusually high rate of pollination and seed-dispersal by birds (Aizen & Escurra, 1998). While large and medium-sized mammals are poorly represented in NHNP's forests (Barnosky et al., 2001), small mammal diversity equals that found in temperate forest elsewhere (Pearson, 1983). Three possible evolutionary paths have been identified for the resident small mammals: (a) evolved in situ from tropical or subtropical relatives (Huchon & Douzery, 2001), (b) relicts from earliest dispersal events (Martin, 2010), or (c) dispersed through a tropical filter (Leite et al., 2014).

Agricultural economies can conflict with natural area protection (Raffaele et al., 2014). Additionally, tourism constitutes a risk; the number of visitors increases annually in NHNP and generates a service demand and consequent economic–ecosystem conflicts (Martin & Chehébar, 2001; Monjeau et al., 2005). Introduced plants, vertebrates and invertebrates have substantially affected forest in NHNP (Arbetman et al., 2012; Barrios Garcia Moar, 2012; Correa et al., 2012; Franzese & Ghermandi, 2014; Nuñez et al., 2013; Rodriguez-Cabal et al., 2013; Simberloff et al., 2002; Svriz et al., 2013). Also, a combination of natural and anthropogenic factors has increased wildfire severity in Patagonia more widely (Davis et al., 2019; Godoy et al., 2019; Paritsis et al., 2013; Raffaele et al., 2014; Tiribelli et al., 2019; Urretavizcaya & Defossé, 2019).

Many problems in NHNP have been identified through scoring or PA management effectiveness evaluations, but no clear evidence shows to what extent they impact resident small mammals, since most information regarding flora and fauna was limited to inventories (Rusch, 2002). In an ecosystem with low vertebrate diversity like NHNP, small mammals (particularly rodents) affect forest dynamics and constitute the main food of many other species (Raffaele et al., 2014). Nevertheless, because rodents are small and fecund, the general perception is that they occur in high density and require little area, so they can persist in a fragmented landscape, which may not be true for all species (Lidicker, 1989). Small mammal species extinctions and distribution contractions have been reported in northern Patagonia (Teta et al., 2014).

We aimed to assess potential differences in species richness and abundance in NHNP by monitoring its small mammals. We proposed that communities inhabiting the Strict Reserve Areas will be richer and more abundant because they lack human intervention. Increasing contact with human activities and presence along the gradient National Park–National Reserve–unprotected area could be reflected in impoverished small mammal communities.

METHODS

Study site

We conducted our study in 2015 and 2016 in NHNP in the Andean foothills of Argentina (Fig. 1). Average temperatures range from 3°C (July) to 15°C (January). Precipitation is greatest in austral autumn and winter, averaging 1,800 mm annually. The area lies within the southern temperate forest in the sub-Antarctic biogeographic province, with the Patagonian Steppe ecoregion also represented along the eastern, drier fringe (Mermoz & Martin, 1986). Southern Beeches (*Nothofagus dombeyi*, *N. pumilio*, *N. antarctica*) and Chilean Cedar (*Austrocedrus chilensis*) dominate the canopy, and Bamboo (*Chusquea culeou*) and several species of shrubs and smaller trees the understory (Dimitri, 1977). Elevation (from 500 to 3554 m.a.s.l.), water availability and dominant species are inter-related. Differences in biological outcomes measured in different ecological conditions might reflect variation of those conditions rather than the management approach (Barnes et al., 2017). To reduce such variation, we worked entirely in *N. dombeyi*-dominated forest between 500 and 700 m a.s.l.

Sampling method

We implemented a widely used strategy to assess PA effectiveness, comparing communities inside and outside of PAs (Coetzee et al., 2014). We conducted a capture-mark-recapture study to evaluate small mammal communities across three different protection levels and outside of NHNP, establishing 20 plots (60 x 60 m) at least 1 km apart, five each in the Strict Reserve, National Park, National Reserve and outside the NHNP (Fig. 1). NHNP is bounded to the north by Lanin National Park, to the west by Chile, and to the east changes to a different ecoregion (steppe), leaving the southern region as the only comparable non-protected area with forest dominated by *N. dombeyi* and within the elevation range mentioned above. Accessibility to these private lands is restricted by the main road (RP83). Plot selection took into account walking distances to allow early release of trapped animals. In 2015, we also established two extra plots on Isla Victoria (the largest island in Nahuel Huapi Lake) in an area

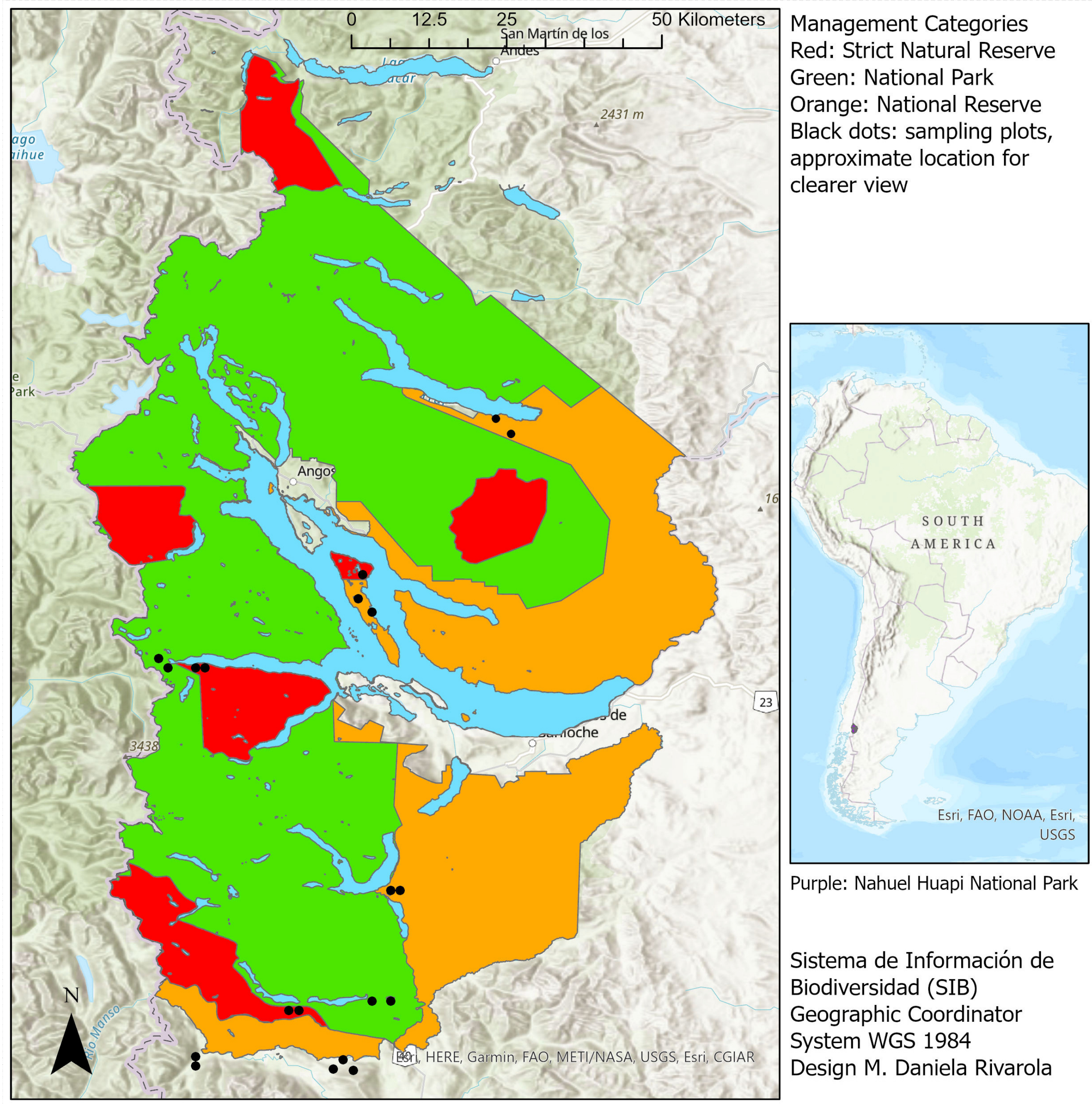

Figure 1. Map of NHNP with protection categories indicated with different colours. Red: Strict Reserve, Green: National Park, Orange: National Reserve. Dots indicate sampling plots (which were at least 1,000 m apart).

where natural forest was replaced by Douglas Fir (*Pseudotsuga menziesii*) plantations approximately 70 years ago. We used a star design for each plot, establishing 25 trap stations 10 m apart, georeferencing the central trap station with a Garmin GPS60. At each station, we activated a Sherman trap (10 x 10 x 29 cm) baited with oats and peanut butter (Pearson & Pearson, 1982) on the ground and a Tomahawk trap (30 x 14 x 14 cm) baited with apple and banana slices (Fonturbel & Jimenez, 2009; Rivarola, 2010) in vegetation 1 m above the ground. We conducted monthly capture sessions during austral summers in 2015 and 2016, activating traps four consecutive nights and checking them at sunrise and at sunset, yielding a total capture effort of 41,600 traps/night. Trap success was calculated as the number of small mammals caught divided by the number of active traps.

We identified each individual captured to species. Before releasing individuals, we marked marsupials with

Passive Integrated Transponders (PIT-Tags, TXP148511B model, Biomark 8.5 mm x 2.12 mm, 134.2 kHz ISO, 0.067g) by subcutaneous implantation on the back and rodents with ear-tags (National Band and Tag Company, style 1005-1). We handled captured animals following UTK-IACUC protocol # 2409-0116 (Institutional Animal Care and Use Committee, University of Tennessee).

To assess sampling area equivalences, we measured vegetation cover and plant species composition in 100 squares (1 x 1 m) per plot both years, and to estimate forest structure we superimposed over each plot a 13 x 13-transect grid, with transects 5 m apart. We defined 169 nodes (one at each transect intersection) where we measured the diameter at breast height (DBH) of the nearest tree (within 1 m radius) or recorded zero for treeless nodes. We estimated tree density by the number of trees over the plot area (3,600 m²). We converted DBH values to obtain basal area per plot (G):

$$G = \frac{\sum g_i}{S_T}$$

where g_i is the stem cross-section area of tree i in m^2 and S_T is the plot area in hectares.

Arthropods are components of small mammal diets in Patagonian temperate forests (Pearson, 1983). We established nine pitfall traps per plot: plastic containers 10 cm in diameter and 15 cm deep half-filled with a water/dishwashing liquid solution. We activated pitfall traps simultaneously with small mammal trapping sessions. We preserved samples in 70 per cent ethanol and recorded abundances as the total number of arthropods per plot.

Data analysis

To compare small mammal diversity between sites under different levels of protection, we used species richness (S), assemblage abundance, and abundance of each species. We used Kruskal-Wallis tests to compare each index across protection levels and conducted post-hoc Tukey's Honest Significance Differences analyses with 95 per cent confidence level when an index varied in response to protection level. To evaluate habitat equivalence between plots, we used ANOVA and Kruskal-Wallis tests to compare vegetation cover, plant species richness, tree basal area, tree density and arthropod abundance. Finally, we analysed these environmental variables with Principal Component Analysis to evaluate clustering of plots within protection levels.

Juvenile *Dromiciops gliroides* feeding on remaining bait after released © María Daniela Rivarola

RESULTS

We had a higher capture effort in 2016 but higher capture success in 2015 (Table 1). We trapped no small mammals in the two plots established in 2015 in areas dominated by Douglas Fir, despite a capture effort of 2,100 traps/night.

In 2015, we trapped seven rodents – Long-haired Mouse *Abrothrix hirta*, Olive Grass Mouse *A. olivacea*, Long-tailed Pygmy Rice Rat *Oligoryzomys longicaudatus*, Long-clawed Mole Mouse *Geouxus valdivianus*, Andean Long-clawed Mouse *Chelemys macronyx*, Chilean Climbing Mouse *Irenomys tarsalis*, Southern Big-eared Mouse *Loxodontomys micropus* – and the endemic marsupial Monito del Monte *Dromiciops gliroides*. In 2016, we captured the same species except for *C. macronyx*. *A. hirta*, *D. gliroides* and *O. longicaudatus* were by far the most abundant across the four levels of protection in both years (Figure 2).

Species richness did not vary among levels of protection in 2015 or 2016 (Table 2). However, assemblage

Table 1. Summary of small mammals captured during 2015 and 2016. Capture effort for two extra plots in area dominated by Douglas Fir during season 2015 not included here.

	Summer 2015	Summer 2016
Capture effort	20,600 trap nights	21,000 trap nights
Number of individuals caught	727	532
Total number of captures	2,102	1,894
Capture success rate	10.20%	9.02%

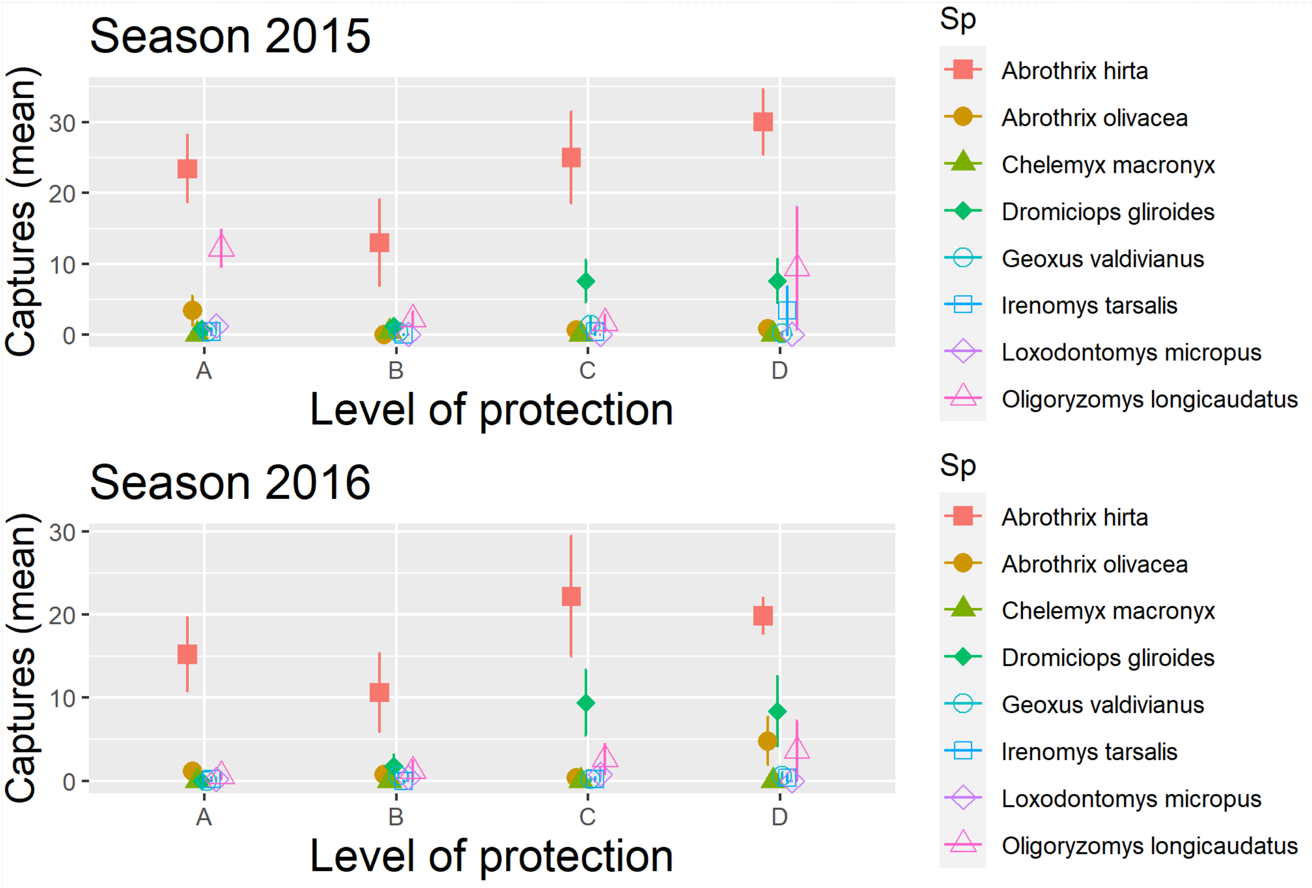

Figure 2. Diversity and average abundance of small mammals caught across different protection levels in NHNP during summer 2015 (top) and 2016 (bottom). (A) outside NHNP, (B) National Reserve, (C) National Park, (D) Strict Reserve

Table 2. Comparison among small mammal communities across different protection levels in the NHNP system and outside. Each variable (column 1) was analysed for each year independently by Kruskal-Wallis Test. Mean ± standard error is indicated in each cell. * indicates statistical significance

		Outside NHNP	National Reserve	National Park	Strict Reserve	KW X^2	df	P-value
Species Richness	2015	3.8 ±0.66	3.0 ±0.74	3.0 ±0.54	3.2 ± 0.37	0.853	3,16	0.8368
	2016	2.2 ±0.49	3.0 ± 0.32	2.8 ±0.66	3.0 ±0.54	4.1315	3,16	0.2476
Assemblage Abundance	2015	41.8 ±8.45	17.2 ±5.91	36.6 ±7.86	51.4 ± 8.26	7.6316	3,16	0.0542*
	2016	17.0 ±3.99	15.4 ±5.55	35.8 ±7.08	37.6 ± 3.75	9.2491	3,16	0.0261*

abundances were greatest in the highest level of protection and lowest in the lowest level of protection in both years (Table 2; Tukey test [p = 0.0287 for 2015 and p = 0.0399 for 2016]). Finally, abundance by species across the NHNP system and outside PAs differed only for *L. micropus* and *D. gliroides* (Supplementary Online Material, Table 1). *Loxodontomys micropus* was trapped only outside the PA in 2015; this difference did not persist in 2016.

A Kruskal-Wallis test on abundance of *D. gliroides* vs protection level yielded p = 0.0381 in 2016; however, the subsequent Tukey test did not indicate a significant difference between any pairs; thus these results should be interpreted with caution. Nevertheless, *D. gliroides* abundances appeared greater in the National Park and Strict Reserve than in the National Reserve and outside the PA. To evaluate these unequal abundances further, we combined capture numbers from the Strict Reserve and National Park as 'High protection' and National Reserve and outside NHNP as 'Low–no protection'. Each year saw a difference between these groups (2015, t = 3.2188, df = 9.4882, p = 0.0098; 2016: t = 2.8567, df = 10.16, p = 0.0168).

Most environmental variables showed no differences among treatments, suggesting habitat equivalence. We evaluated forest structure with two variables (tree basal area and tree density). While the former manifested no difference among protection levels (F = 2.162, df = 3, 16, p = 0.1324), the latter showed a marginal difference between the National Reserve and National Park (F = 3.218, df = 3, 16, p = 0.051, Tukey test p = 0.049). Ground vegetation cover and plant richness were analysed separately by year. While vegetation cover did not differ among treatments both years (F = 1.801, df = 3, 16, p = 0.187, and KW chi-squared = 3.549, df = 3, 16, p = 0.314 for 2015 and 2016, respectively), plant species richness was consistently higher in the unprotected area (F = 7.813, df = 3, 16, p = 0.002 for 2015, and KW chi-squared = 13.16, df = 3, 16, p = 0.004 for 2016, Supplementary Online Material, Figure 1).

Finally, arthropod abundance did not vary among levels of protection (chi-squared = 1.1102, DF 3, p = 0.7746 and chi-squared = 5.7657, DF = 3, p = 0.1236, for 2015 and 2016 respectively).

We evaluated clustering of plots within protection levels using PC1, PC2 and PC3, which accounted for over 80 per cent of environmental variation (Supplementary material, Table 2). No clear clustering of plots occurred within protection levels (Figure 3).

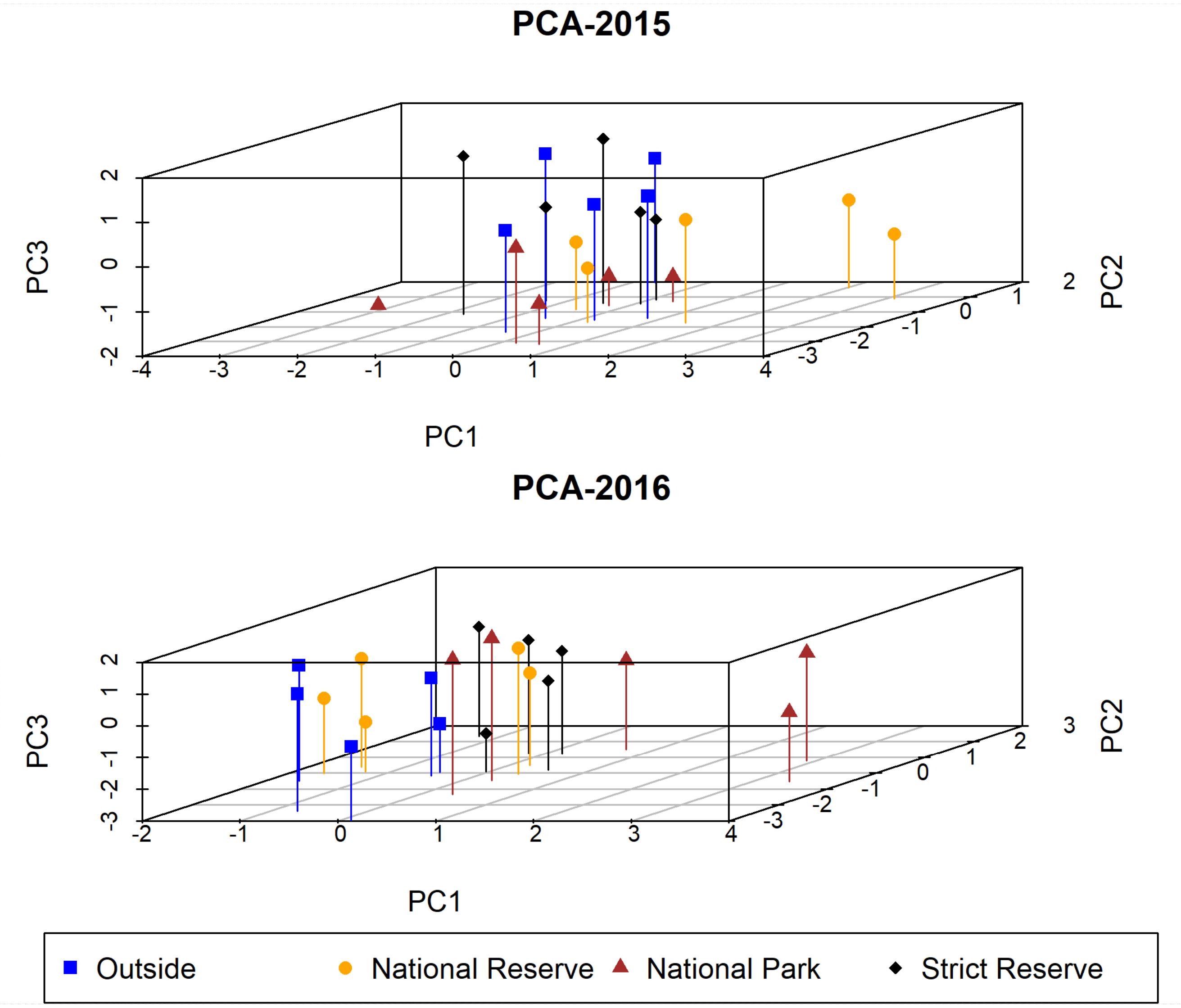

Figure 3. Lack of clustering of plots within protection levels using PC1, PC2 and PC3. Top 2015, bottom 2016.

DISCUSSION

Assessing PA effectiveness by comparing PAs across levels of protection or with unprotected areas is hindered by selection bias – the initially protected site may have been selected as it was especially likely to favour the persistence of target species (Ferraro, 2009; Joppa & Pfaff, 2010). When NHNP was established in 1922, the vicinity of unprotected plots did not differ in evident ways from the area that later became NHNP, and by choosing all plots in a narrow elevational range dominated by *N. dombeyi* and with no apparent anthropogenic impacts, we attempted to minimise the possible influence of factors other than the level of protection. The division in 1968 of NHNP into a National Park largely in the west and National Reserve largely in the east located most private properties that existed before park establishment in the National Reserve, while the sites designated Strict Reserve in 1990 were generally in more pristine areas but "did not necessarily respond to ecological criteria of conservation" (Margutti & Arosteguy, 2019). None of these designations are specifically aimed at small mammal conservation. Again, we aimed to minimise the influence of factors other than protection levels by limitations on plot features, but we cannot rule out a degree of selection bias.

Two PA evaluations have been conducted in Patagonian temperate forest using different methods. A management effectiveness evaluation based on stakeholders and field personnel questionnaires and interviews aimed to assess four key elements: context, planning, inputs and processes. NHNP performance was scored as 'fairly satisfactory' (scoring 51–75 per cent of optimal), with internal disorganisation, reduction in funding, inadequate use of budget and political weakness due to external pressure noted (Rusch, 2002). However, lack of monitoring for most resident species, particularly small mammals, prevents assessment of the effectiveness of current management for these communities. NHNP is part of 4,817,000 ha of North Andean Patagonian Corridor (Chile–Argentina), an area internationally recognised as a biodiversity hotspot (Margutti & Arosteguy, 2019); however, the PAs along the Patagonian Andes in Argentina were created during the 1930–1940s, in response to an international boundary dispute with Chile and preference for protecting forests over other ecosystems (Rivarola et al., 2021). A second evaluation assessed coverage of endemic species. Endemism areas determined using parsimony analyses of endemism based on the known distribution of five unrelated taxa (ferns, trees, reptiles, birds and mammals) concluded that the coverage of this PA corridor (including NHNP) poorly overlapped with the Patagonian hotspot (Rodriguez-Cabal et al., 2008).

Creating a species conservation priority list of Patagonian vertebrates was proposed as an inexpensive, rapid tool to use resources allotted to biodiversity protection efficiently (Christie, 1984a). Detailed monitoring methods such as that presented here could help validate or update such lists. The conservation status of the 32 resident mammal species of NHNP was assessed in 1994 (Úbeda et al., 1994). The study considered two protection levels, National Park (high) and National Reserve (low) and defined 14 variables believed relevant for species survival and conservation, assigning scores to each. However, using variables such as body size, feeding behaviour and reproductive potential yielded low scores for small mammals, which could bias results against this group as suggested for previous studies (Lidicker, 1989). Most species recorded in our study occupy the bottom part of the priority list proposed by Úbeda et al. (1994). *Dromiciops gliroides* was the exception, ranked tenth in this list, declared vulnerable in Argentina (Diaz & Ojeda, 2000), and listed as Near Threatened because its population is declining mainly owing to habitat changes, especially forest conversion to agriculture and habitat fragmentation (IUCN Red List; Martin et al., 2015). It is remarkable that *D. gliroides* was the third and second most abundant species in 2015 and 2016, respectively (Supplementary material, Fig. 2). However, these populations were smaller than those previously reported in Argentina (Rivarola, 2010) and Chile (Fonturbel et al., 2012). The first long-term study tracking population changes in this species demonstrated yearly variation associated with natural events (Balazote Oliver et al., 2017). Importantly, we trapped most individuals in plots with a high protection level (Strict Reserve and National Park). Although the seven rodent species identified in our study had low conservation priority, a comparative study evaluating the potential consequences of European colonisation in the region reported a population contraction for six of these species, with the only exception being the opportunistic *O. longicaudatus* (Teta et al., 2014).

To minimise the effect of landscape variation on species presence/absence and abundance, we restricted our plots to forest dominated by *N. dombeyi*, since it constitutes the species with the broadest distribution and dominance within NHNP, aiming to relate community and population variation to protection levels. The absence of native small mammals in the Douglas Fir plantation agrees with previous studies in northern Patagonia (Lantschner et al., 2011). Pearson

Nahuel Huapi National Park, Lake Huala Hue (front) and Lake Steffen (middle) in National Park category. Lake Martin (back) in Strict Reserve category © María Daniela Rivarola

(1983) described nine species in the most comprehensive small mammal study in northern Patagonian forests. We recorded all but *Aconaemys fuscus*, whose distribution occurs north of NHNP (Roach, 2016). Our analysis yielded scant evidence that the NHNP different protection categories are effectively conserving small mammals. Nevertheless, the different protection categories did not actually differ as much as we expected in terms of anthropogenic impacts and park ranger enforcement. Livestock and wildfires have been identified as the major anthropogenic forces in Patagonian forests (Teta et al., 2014). We found cattle (domestic, semi-wild or wild) in almost every plot, and wildfires are frequent every year across the region. Over the course of this study, we witnessed areas that encompass both National Park and Strict Reserve without a park ranger on duty during the tourist season and with hundreds of daily visitors who move at will into the Strict Reserve, including areas lacking trails and surrounded by rivers and lakes where a ranger lacked the boat required to patrol the area. The park vehicles are outdated and in poor condition, thus are unreliable for patrolling this rough terrain (Monjeau et al., 2005; Rusch, 2002).

Abrothrix hirta exceeded all other species in abundance and distribution (Supplementary Online Material, Figures 2 and 3), in agreement with previous studies (Christie, 1984b; Pearson & Pearson, 1982). Although a typical forest species, *A. hirta* is found in steppe with sufficient ground cover and bushes (Pearson, 1983). This habitat breadth plus its omnivorous feeding behaviour could be associated with its numerical dominance. *Oligoryzomys longicaudatus* has been described as scarce in dense forest (Pearson, 1983). However, it was the second most abundant species trapped during 2015 and the third most abundant species in 2016 (Supplementary Online Material, Figure 2). As abundance and protection level were unrelated, this decline could be due to a natural process. The other rodent species and *D. gliroides* combined accounted for 8.84 per cent of the assemblage abundance in 2015 and 10.17 per cent in 2016. Their low numbers and uneven distribution (Supplementary Online Material, Figures 2 and 3) suggest that conclusions based on these data are preliminary.

Small mammals have been proposed as indicators of habitat disturbance both in unprotected (Olifiers et al., 2005) and PAs (Avenant, 2000; Stephenson, 1993). However, small mammal populations commonly undergo cycles of different length responding to biotic and abiotic factors (Armas et al., 2016; Murua et al., 1986), which suggests that their use to assess landscape disturbances or management effectiveness requires a multi-year approach (Avenant, 2011, Pearce & Venier, 2005). Lack of this information for the communities in this area renders tenuous our conclusion regarding NHNP effectiveness and highlights the importance of long-term studies and regularly scheduled monitoring programmes. This study is the first attempt to fill this gap. Our data provide evidence on changes in species abundances not only yearly, but also monthly.

The higher assemblage abundance recorded both years inside the Strict Reserve suggests that direct human interaction negatively affects this assemblage, a situation particularly important for *D. gliroides*, an endemic and Near Threatened species and the only living species of the order Microbiotheria. Species inhabiting plots near human settlements might suffer predation by domestic cats. *Dromiciops gliroides* was preyed on by domestic cats in a municipal PA in Bariloche (Di Virgilio et al., 2014). Interestingly, the four plots located in the area of Puerto Blest, where no domestic cats are present, recorded the highest abundances of *D. gliroides*. In general, areas where we found more diversity and abundance were located in zones with more difficult access (accessible only by boat or walking), possibly implying it is not the protection category but primarily the inaccessibility that is preserving these communities, as has happened in forest PAs elsewhere (Struhsaker et al., 2005; Joppa et al., 2008).

In 2019, the National Parks Administration (APN) approved a management plan for NHNP (Margutti & Arosteguy, 2019). Weaknesses and strengths of the current system were identified. A continuous cycle of planning and feedback through an annual operational planning was proposed as the best strategy to achieve the conservation goals of NHNP. Monitoring of species of special value is part of the continuous evaluation process. *Dromiciops gliroides* is included in this list. Our study would provide an important baseline regarding the distribution and relative abundance of the species, since to the best of our knowledge our study provides the most comprehensive dataset mapping the distribution of *D. gliroides* in NHNP.

SUPPLEMENTARY ONLINE MATERIAL

Supplementary tables, figures and species information

ACKNOWLEDGEMENTS

This research was supported by the Nancy Gore Hunger Professorship in Environmental Studies at the University of Tennessee. We are grateful to two anonymous reviewers and Dr Geldmann for their valuable feedback and suggestions. Our special thanks to NHNP rangers and Prefectura Naval Argentina officers for help in the field, and our field assistants: Ludovico Zeller, Isabela Zeller, Emmanuel Imizcoz, Lucila Amione, Flavia Casinelli, Marlene Zaracho, Edgardo Balverdi, Ana Blazina, Thais Efron, Celeste Lado, Florencia Mallou, Laura Barbieri, Sofia Jones, Julieta D'Amario, Carolina Mansilla, Belen Dri, Antonio Navarro, Sabrina Ignacio, Mauro Ricci, Natanael Griffa, Francisco Molina and Pilar Rivarola.

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RESUMEN

Las áreas protegidas son la piedra angular de las estrategias de conservación, pero su eficacia es cada vez más cuestionada. En el Parque Nacional Nahuel Huapi de Argentina, comparamos pequeños mamíferos en áreas no protegidas y en áreas con tres niveles de protección: (1) actividad humana prohibida, (2) recreación autorizada, y (3) turismo y usos extractivos autorizados. Un estudio basado en la captura, marcaje y recaptura en cinco parcelas de cada tipo de área incluyó un esfuerzo de captura mediante la colocación de 41.600 trampas/noche. En 2015, atrapamos siete especies de roedores autóctonos y un marsupial endémico. En 2016, capturamos las mismas especies salvo un roedor. La abundancia de especies no varió entre los niveles de protección. Sin embargo, las mayores abundancias se dieron en el nivel de protección más alto y la abundancia más baja en el nivel más bajo. Hallamos poca evidencia de que el sistema de protección del Parque Nacional Nahuel Huapi preserva de manera sustancial los pequeños mamíferos. Sin embargo, las mayores abundancias en el nivel de protección más alto sugieren que la interacción humana directa afecta este conjunto de manera negativa.

RÉSUMÉ

Les aires protégées constituent la pierre angulaire des stratégies de conservation, mais leur efficacité est de plus en plus remise en question. Dans le parc national Nahuel Huapi en Argentine, nous avons comparé les petits mammifères dans les zones non-protégées et dans des zones avec trois niveaux de protection : (1) activité humaine interdite, (2) loisirs peuvent être autorisés et (3) tourisme et utilisations extractives autorisés. Une étude de capture-marquage-recapture sur cinq secteurs dans chaque type de zone comprenait le piégeage de 41 600 pièges/nuit. En 2015, nous avons piégé sept espèces de rongeurs indigènes et un marsupial endémique. En 2016, nous avons capturé les mêmes espèces à l'exception d'un rongeur. La richesse des espèces ne variait pas selon les niveaux de protection. Cependant, les abondances les plus élevées se trouvaient dans le niveau de protection le plus élevé et les abondances les plus faibles dans le niveau le plus bas. Nous avons trouvé peu de preuves que le système de protection du parc national Nahuel Huapi préserve substantiellement les petits mammifères. Cependant, des abondances plus élevées dans le niveau de protection le plus élevé suggèrent que l'interaction humaine directe affecte négativement cet assemblage.